



Multimedia Communication Systems I

Digital TV: Overview

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Outline

- Development history for Advanced Television
 - Compatible vs. Simulcast for ATV development
 - Japan and Europe ahead with analog HDTV
 - US adopt all-digital approach
- US DTV (Grand Alliance System) overview
 - Video
 - Audio
 - Multiplexer
 - Modulation (more on modulation and error control in next lecture)
 - DTV rollout plan and spectrum auction
- DVB system of Europe
- ISDB system of Japan

Overview of TV System Development

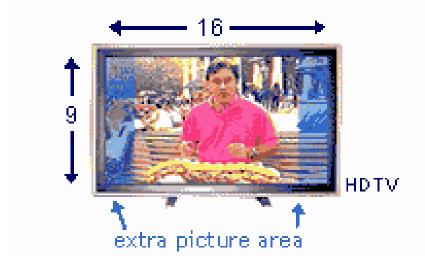
- Analog Black and White TV: 1940
- Analog Color TV: 1950
- Cable TV, Satellite TV, VCR
- Digital TV through small dish satellite (MPEG2 encoded), early 90's
- DVD (MPEG-2 encoded), mid 90's
- Transition to Digital TV: SD and HD (MPEG-2 encoded): 1990-2006-?
- Phase out analog TV: 2006? 2009?

Advanced Television System (ATV)

- Generally referred to television systems that offer better video and audio quality than current analog TV systems (NTSC/PAL/SECAM)
- SDTV (standard definition TV): with resolution equivalent to analog TV systems (BT.601: 480x720,60i, or 576x720,50i), with aspect ratio of 4:3
- HDTV (high definition TV): with wider aspect ratio, approximately twice the resolution horizontally and vertically
- EDTV (enhanced definition TV): between SDTV and HDTV

Why HDTV

HDTV is 1/3 wider than NTSC





Having the screen occupy a great field of view (especially peripherally) significantly increases the sense of "being there".

Movies have adopted wider screen (up to 2:1 in aspect ratio) since 1980's

Possible Routes to ATV

- Compatible system
 - Supply additional signal that can augment existing analog system, which can be offered in a separate channel
- Simulcast system
 - Incompatible with existing system, but co-exist during transition period, and phase out the current system eventually

Japan/Europe Ahead with Analog HDTV

- Japan: MUSE (multiple sub-Nyquist sampling encoding) system, 1025 lines/frame, requiring 20 MHz bandwidth in raw, reduced to 8.15 MHz, used for Satellite HDTV broadcast since 1980
- Europe: MAC (multiplexed analog components) system. HDTV broadcast using MAC was planned for 1995, but it never happened
- US lagged behind in ATV development
 - 1987: FCC issued a ruling that HDTV should be compatible with NTSC and be confined to existing UHF and VHF frequency bands
 - Many analog or mixed (analog/digital) HDTV proposals were submitted and tested since 1987

US Went for All-Digital HDTV (late but better !)

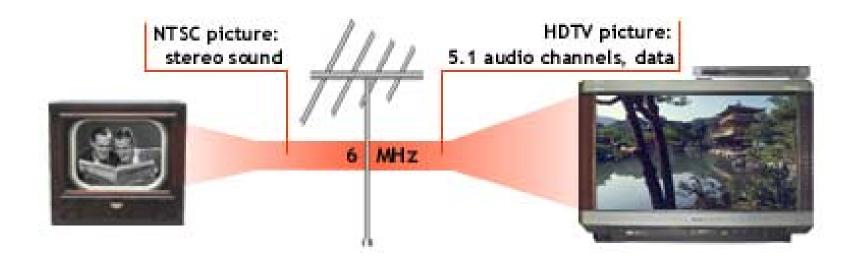
- Key FCC decisions in 1990
 - Simulcast in 6 MHz (non-compatible with NSTC) rather than augmentation of NTSC, releasing some of the allocated NTSC spectrum after transition to new standard is completed
 - Direct transition to HDTV rather than going through EDTV (enhanced over NTSC), but each HDTV channel can only use 6 MHz
- 1990-1991, four all-digital HDTV proposals are presented to FCC
- 1993: FCC decided on the all-digital approach, and recommend the competing teams to form an alliance to develop a standard for US HDTV system

Digital HDTV Grand Alliance

- March 1993: Digital HDTV Grand Alliance formed (AT&T, GI, Philips, MIT, Sarnoff, Zenith, Thomson)
 - Goal: to combine the best features of four separate proposals to create a "best of the best" HDTV system
 - Late 1994: First Grand Alliance HDTV prototype system tested
- Late 1995: FCC/ATSC adopted the Grand Alliance HDTV proposal (which can broadcast in different video format) as the digital TV (DTV) standard for US
 - Including both SDTV and HDTV
- But actual transition to DTV has been slow!

ATSC Digital Television Standard, Rev. B (A/53B), 7 August 2001 (Amendment 1 dated 23 May 2002; Amendment 2 dated 19 May 2003), available at http://www.atsc.org/standards.html

Challenge: HDTV Still Has to Fit in 6 MHz



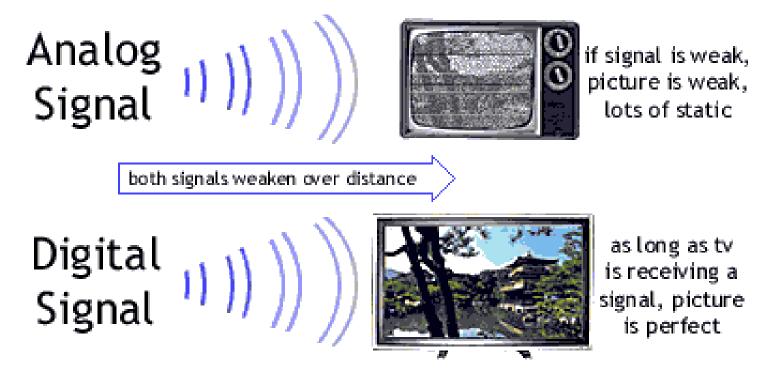
From http://www.pbs.org/opb/crashcourse/digital_v_analog/squeeze.html

Achieved by advanced video coding (MPEG-2 video), audio coding (Dolby AC3) and advanced modulation technique

Why the Digital Approach Win?

- Enable deployment of advanced video/audio coding techniques
- Enable deployment of digital communication techniques (more immune to noise)
- Enable packetized transmission, so that Digital TV system can be used to deliver other data
- Compatible with other development in multimedia/computer world (MPEG-2 primarily)
- Possible to accommodate multiple video formats, targeted for different applications
- Free up spectrum!

DTV Reception

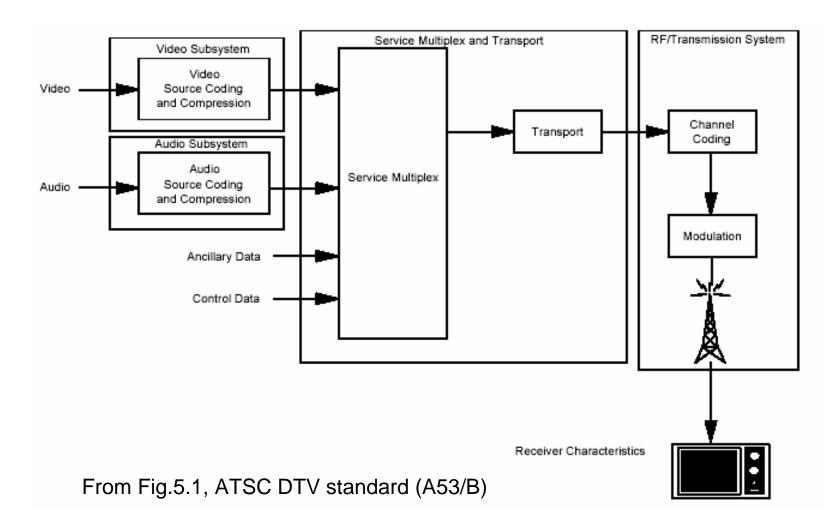


Otherwise, no picture!

http://www.pbs.org/opb/crashcourse/digital_v_analog/ghosts.html

Digital TV

DTV System Model



Major Components of the DTV Standard

- Proved by ATSC (Advanced Television System Committee of FCC), Aug 2001
- Based on the Grand Alliance HDTV proposal
- Video encoding: MPEG2 video (<u>mp@ml</u> for SDTV, <u>mp@hl</u> for HDTV)
- Audio encoding: Dolby AC3 (5.1 channel)
- Multiplex and transport: MPEG2 transport stream syntax
- Channel coding and modulation: digital VSB
 - Terrestrial: 8-level VSB, enabling 19 mbps payload in 6 MHz channel
 - Cable: 16-level VSB, enabling 38 mbps payload in 6 MHz channel
 - Industry has adopted 16-QAM instead

Video Coding

- Use MPEG-2 video standard for video coding (<u>mp@ml</u> for SDTV, <u>mp@hl</u> for HDTV)
- At the highest resolution (SMPTE274M), the raw data rate with 4:2:2 color format is approximately 1 Gbps (1920*1080*30*8*2=1Gbps)
- 6 MHz terrestrial channel with 8 VSB -> 20 Mbps
- 50:1 compression is needed!
- Reduction from 4:2:2 to 4:2:0 gains 2:1.5=1.33:1 compression

Profiles and Levels in MPEG-2

			Profile						
			Simple (I, P) (4:2:0)	Main (I, P, B) (4:2:0)	SNR (I, P, B) (4:2:0)	Spatial (I, P, B) (4:2:0)	High (I, P, B) (4:2:0; 4:2:2)	Multiview (I, P, B) (4:2:0)	4:2:2 (I, P, B) (4:2:0; 4:2:2)
	Low	Pels/line Lines/frame fps mbps			352 288 30 4	352 288 30 4		352 288 30 8	
	Main	Pels/line Lines/frame fps mbps	720 576 30 15	720 576 30 15	720 576 30 15		720 576 30 20	720 576 30 25	720 512/608 30 50
Level	High- 1440	Pels/line Lines/frame fps mbps	1440 1152 60 60		1440 1152 60 60	1440 1152 60 80	1440 1152 60 100		
	High	Pels/line Lines/frame fps mbps	1920 1152 60 80			1920 1152 60 100	1920 1152 60 130	1920 1152 60 300	

Profiles: tools

Levels: parameter range for a given profile

Main profile at main level (<u>mp@ml</u>) is the most popular, used for digital TV

Main profile at high level (mp@hl): HDTV

4:2:2 at main level

(4:2:2@ml) is used for studio production

I, P, B: allowable picture types. Maximum bit rates include all layers in case of scalable bit streams.

Multiple Video Formats Supported

Standard	Active Lines	Active Samples/line	Frame rate
SMPTE274M	1080	1920	24p,30p, 60i
SMPTE296M	720	1280	24p,30p,60p
BT.601-4	483	720	24p,30p,60i/p

Color coordinate: RGB->YCbCr, 4:2:0

US strategy: Going to digital and HDTV simultaneously!

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Digital TV

Multicasting SDTV Programs



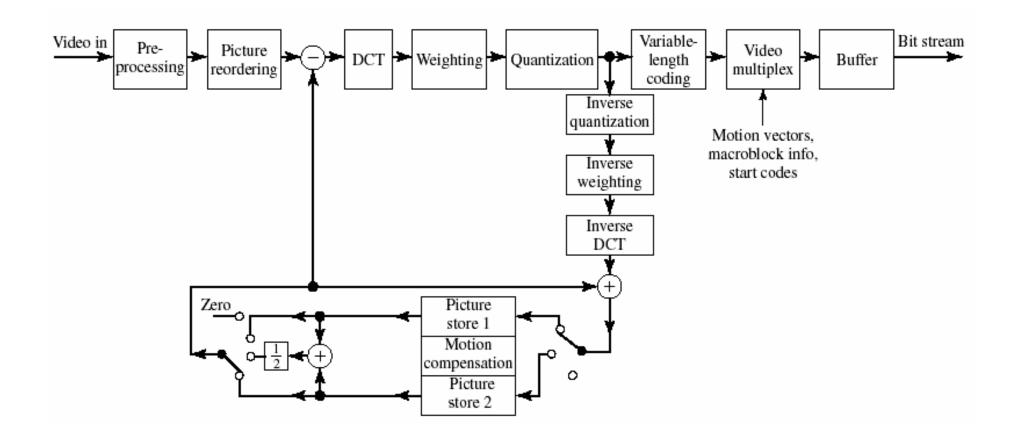
In one 6 MHz channel, four SDTV programs can be multicast instead of only one HDTV program

http://www.pbs.org/opb/crashcourse/digital_v_analog/multicast.html

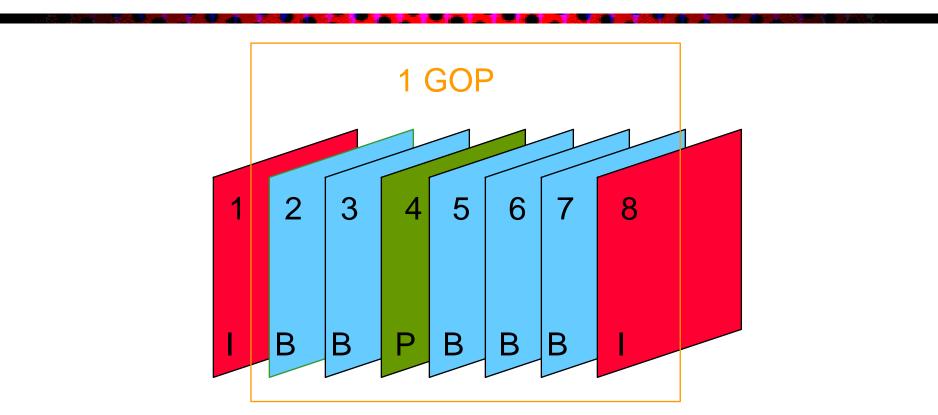
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Digital TV

Video Coding Block Diagram (MPEG1/2)



Group of Picture Structure in MPEG



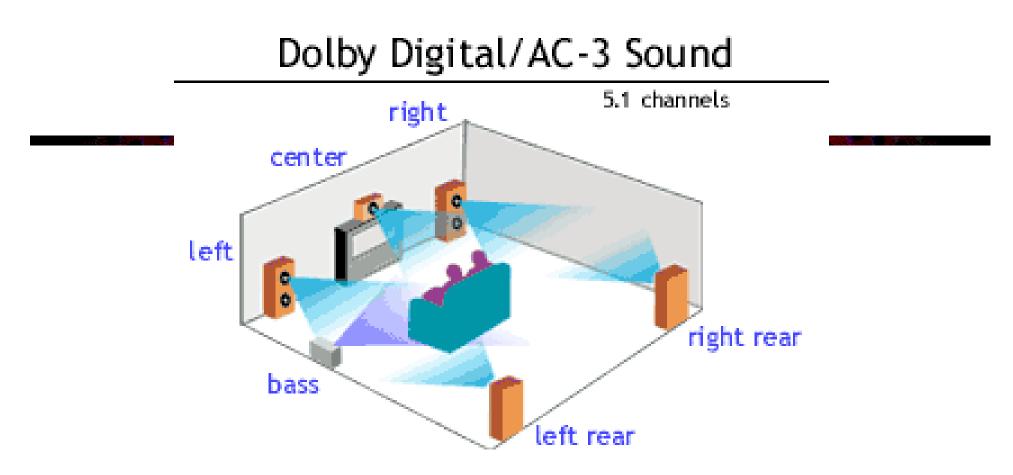
The GOP structure allows random access within the same video stream (for DVD). It also enables channel-surfing. After a viewer changes to a different TV channel, decoding starts at the first encountered I-picture in the new channel. For DTV, the recommended GOP length is ≤ 0.5 sec, to have acceptable delay after channel-change.

Coding Units and Headers

- Sequence
 - Group of pictures (GOP) (BBPBBPBBI, BBPBBPBBI)
 - Picture (I, B, or P-picture)
 - Slice (a complete or partial row of macroblocks)
 - » Macroblock
- Headers are inserted at the beginning of each unit, GOP and picture headers are useful for random access/channel switching, slice and macroblock headers help resynchronize encoder and decoder, in the presence of transmission errors

Motion Estimation

- Half-pel accuracy
- Differentially coded within each slice
- Has different modes to handle progressive and interlaced sequences
 - Field prediction for field pictures
 - Field prediction for frame pictures
 - Dual prime for P-pictures
 - 16x8 MC for field pictures



http://www.pbs.org/opb/crashcourse/digital_v_analog/sound.html

Same digital sound used in most movie theaters, DVDs, and many home theater systems since the early 1990's.

48 KHz sampling rate per channel.

Combined 5.1 channels <= 576 kbps, Each channel <=128 kbps.

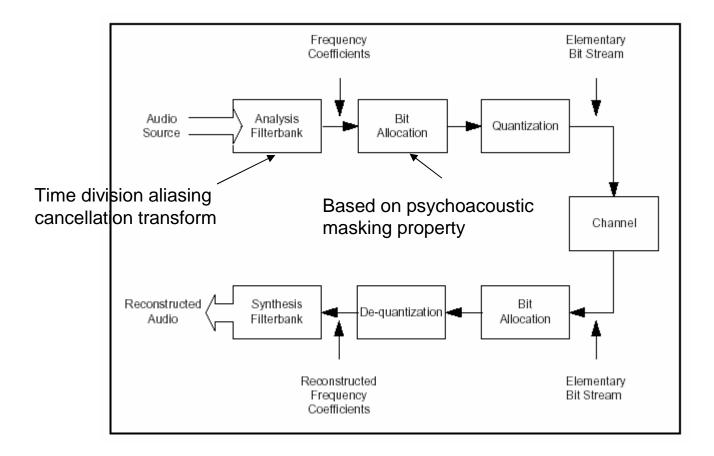
Why Dolby AC3?

- Same digital sound used in most movie theaters, DVDs, and many home theater systems.
- An earlier FCC ruling has specified HDTV audio format to have 5.1 channel
- Dolby AC2 was a strong contender
- Improved to AC3
- Signal bandwidth: 20 KHz per audio channel, except the bass (120Hz).
- Sampling frequency: 48 KHz per channel
- Compressed bit rate: 5.1 channels <= 576 kbps, Each channel <=128 kbps.

Perceptual Audio Coding Revisited

- Decompose a signal into separate frequency bands by using a filter bank or a transform
- The quantization step-size for each frequency band is set so that the quantization noise is just below the masking level of the human auditory system
- The masking level is determined based on the signal level at this frequency (threshold-in-quiet) and on the signal levels at adjacent frequencies in the same time interval (frequency masking) and the signal levels at adjacent frequencies in the neighboring time interval (temporal masking)
- For each block of data, a bit-allocation unit is used to compute the necessary number of bits for each transformed coefficient based its own magnitude as well as the magnitudes of neighboring frequencies in this block, as well as those in adjacent blocks.

AC3 Audio Coding Block Diagram



From Fig.6.2, Guide to ATSC DTV standard (A54)

Digital TV

Audio Coding Units

- Audio sequence
 - AC3 sync frame (1536 samples, 32 ms)
 - Coding blocks (512 samples, but including 256 previous samples), 5.33 ms apart
 - 6 blocks in each sync frame

Processing Steps for Each Block

- Apply a windowing function to taper boundary effect
- Apply the Time division aliasing cancellation (TDAC) transform, producing 256 coefficients
- Each coefficient normalized (maximum=1) and represented using binary code
 - Mantissa is quantized to 0-16 bits, using perceptually weighted bit allocation
 - Exponent and quantized mantissa are converted to binary bits
 - Exponent coding: using inter-block and intra-block prediction, on average 0.39 bits/exponent

Difference with MPEG2 Audio Used in Europe DVB Systems

- MPEG2 uses a different transform (cosine modulated filter bank)
- MPEG2 consists of two subsets
 - MPEG2 BC (backward compatible with MPEG1), considering only up to stereo audio
 - MPEG2 AAC (advanced audio coding), can handle 5.1 channels or more, produce indistinguishable quality at significantly lower bit rates than MPEG2 BC.
 - DVB standard only requires MPEG2 BC compliant decoders, MPEG1 Layer II is recommended
 - DVB's main target is SDTV, not HDTV

DTV Rollout Plan

• April, 1997

FCC gives broadcasters \$70 billion worth of spectrum (taboo channels) to broadcast digital alongside analog until 2006. FCC also mandates that in 2006 all broadcasts must be fully digital.

November, 1998
 PBS, ABC, NBC, CBS, and Fox are committed to broadcasting digitally in the top ten U.S. markets (30% of viewers) by Nov. 1.

• May, 1999 Broadcasters must have digital stations in top 30 U.S. markets (50% of viewers).

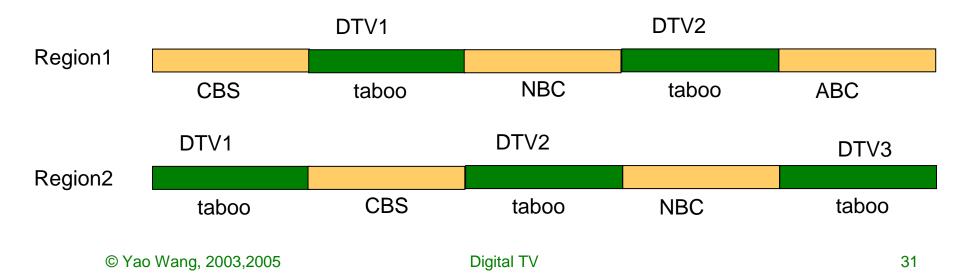
• 2006

Broadcasters must relinquish extra broadcast spectrum and broadcast only digital.

- Only if at least 85% of households in US can receive digital TV
- So far, the progress has been SLOW!
- Newly projected date for stopping analog transmission: April 2009?

DTV Broadcasting During Transition

- FCC requirement
 - In the transitional phase, no new spectrum will be allocated to DTV
 - Broadcasters can use the taboo channel for DTV broadcast
 - In the same service area (50 miles in radius around the broadcast tower), every other 6 MHz channel is not used to minimize interference from other channels. The unused channels are *taboo* channels.
 - The DTV channel must not create interference that adversely affect adjacent NTSC channels, or co-NTSC channels in neighboring regions



Released Spectrum

- Each SDTV channel requires about 1/4 of the analog TV channel
- The transition to DTV would free 108 MHz of spectrum (698— 806 MHz, current UHF channels 52-69) for other services
 - Entire AM radio uses 1.2 MHz
 - WLAN uses 83.5 MHz
- "Beachfront spectrum": ideal for cellular services
 - Signals in this band propagates farther and penetrate buildings better than signals in today's cellular bands (at ~1.9GHz)
 - Fewer cells needed, less infrastructure cost
 - Cell phone companies would like to use it for 3G services: mobile video, wide-band Internet access

Spectrum Auction

- Government will auction off the 108 MHz spectrum
 - Reduce deficit
- 2001-2002: 6 MHz in the 746-806MHz range was auctioned off, totaling \$540 million
- 2002-2003, 18 MHz in the 698-746 MHz was auctioned off, \$145 Million
- 24 MHz reserved for public-safety communications (channels 63,64,68,69)
 - Local governments can decide how to use these channels
- Remaining 60 MHz yet to be auctioned, planned to be done at dates closer to turn off analog services
- Originally projected at a total of \$50 Billion, reprojected at about \$30 Billion
 - Part of it (<\$5 B) will be used to subsidize low-income families converting analog TV sets to digital)

THE FCC AUCTION PLAN

THE UPPER 700

The spectrum band from 746 to 806 MHz is organized into four auction blocks, each with paired channels, plus 24 MHz-reserved for public safety. Blocks A and B, designated as guard bands, were auctioned in 2001 and 2002.

65

180

66

6>

TRIT

THE LOWER 700

The spectrum band from 698 to 746 MHz is organized into five auction blocks, three with paired channels (A, B, and C), two as single channel blocks (D and E). Blocks C and D were auctioned in 2002 and 2003.

NUMBER OF LICENSES

CHANNELEA TON

FREQUENCY MILE

BLOCK

099

6

53

50

200

6

134

55

6

56

6

5>

LOWER 700 MHZ

8

6

59

746 747

60

61

UPPER 700 MHZ

62 102 201

Н

58

10

From R. M. Rast, "The Dawn of Digital TV," IEEE spectrum, Oct. 2005, pp.27-31.

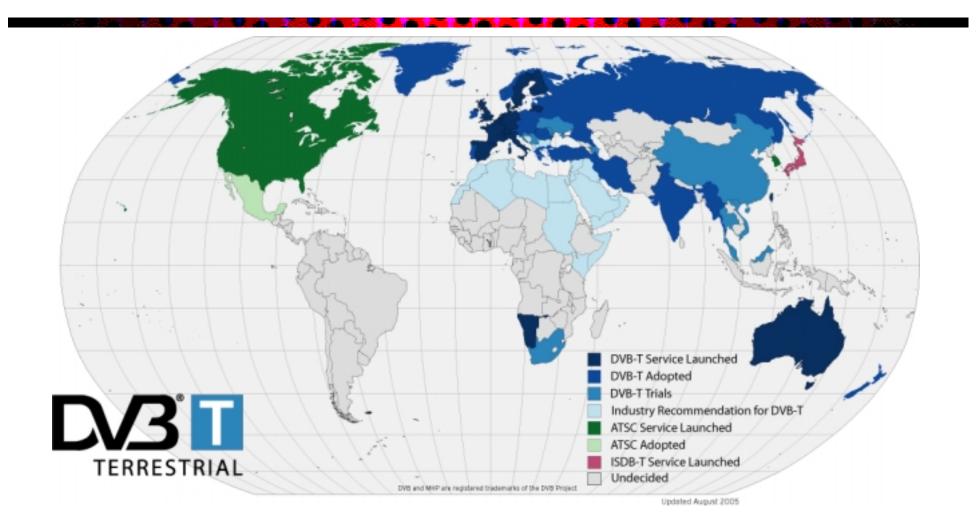
The DVB System (Digital Video Broadcast)

- Widely adopted in Europe
- Video: MPEG-2 video, focusing on SDTV format
- Audio: MPEG-2 audio (only require MPEG2 backward compatible mode, which is equivalent to MPEG1 layers I&II)
- Transport: MPEG-2 transport stream
- Modulation: COFDM (coded orthogonal frequency division multiplexing) over 8MHz channel, offering 24 mbps, more resilient to multipath effect of terrestrial transmission
- With the failure of the MAC HDTV system in mind, Europe went for digital mainly to pack more SDTV programs into each 8 MHz channel, which can be received by adding low-cost adapter in existing TV sets
- UK is ahead of the rest of Europe in adopting DVB: 20% of households receiving digital TV via terrestrial or satellite
- Debate about VBS vs. OFDM has slowed down US DTV development

The DVB Standard Family

- Published by European Telecommunications Standards (<u>ETSI</u>)
- DVB-T: for terrestrial broadcasting
- DVB-S, DVB-S2: for satellite
- DVB-C: for cable
- DVB-H: for handheld receivers

DVB vs. ATSC DTV Deployment



From http://www.dvb.org

DVB-Handheld & IP-Datacast (DVB-H/IPDC)

- Targeting handheld, battery-powered mobile devices (<100 mW)
- 15 mbps in 8 MHz bandwidth in a wide area single frequency network at high speed
- Technical differences from DVB-T
 - Time slicing: burst of data received at a time, power saving 90%
 - 4 mode
 - MPEG-FEC: optional, multiplexer level forward error correction (FEC) to combat channel noise
- Can co-exists with DVB-T
- Technical trials of DVB-H services are currently under way in Germany (Berlin), Finland (Helsinki) and the USA (Pittsburgh)
- DVB-H tutorial
 - http://www.dvb.org/documents//DVB-H_Outline.pdf

Japan's ISDB System

- ISDB: integrated service digital broadcasting
- Terrestrial broadcast started 2003
- Video: MPEG2 video
- Audio: MPEG2-AAC
- Multiplexing: MPEG2-system
- Modulation: modified version of COFDM (has gradual degradation with bad reception)

http://www.dibeg.org/PressR/Brazil010618/Attachment4-status.PDF

What is happening in China?

- Still developing its own terrestrial DTV standard
- Plans to switch to digital completely in 2015
- Cable DTV uses DVB-C currently
- Has its own audio-video coding standard (AVS)
 - http://www.avs.org.cn/en/
 - Using part of the MPEG/ITU coding standards that are royalty free, adding its own innovations
 - Video coding and system part completed Dec,2003
 - Better than MPEG-2, less complex than H.264/AVC
 - http://www.china.org.cn/english/2003/Jul/71266.htm

What you should know

- What are the difference between compatible vs. simulcast approaches
- Why did the all-digital approach eventually win?
- What are the major components of the US DTV system and the major techniques employed in each component
- What are the major difference between US DTV and Europe DVB standards
- Video coding:
 - Both DTV and DVB uses MPEG2-video
 - What are the formats supported?
 - How does the GOP structure enable TV channel switching, what determines the maximum delay after channel switching?
 - Know the video data hierarchy, and why it is important to have headers at different levels of the hierarchy
- Audio Coding
 - Principles behind perceptual audio coding (block diagram)
 - DTV uses 5.1 channel Dolby AC3 audio, DVB uses MPEG2-BC (equivalent to MPEG1 layer II, stereo)

References

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- K. Benson and D. Fink, HDTV, Multiscience Press, 1991
 - Containing description of both analog (MUSE, MAC) and digital HDTV proposals